ISSN (print) 0093-4666 © 2011. Mycotaxon, Ltd. ISSN (online) 2154-8889

MYCOTAXON

http://dx.doi.org/10.5248/117.115

Volume 117, pp. 115–122 *July–September 2011*

New records of rust fungi on sedges (*Cyperaceae*) from Pakistan

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Abstract —*Puccinia caricis-kouriyamensis* on *Carex karoi, P. caricis-pocilliformis* on *Carex* sp., *P. extensicola* var. *linosyridis-caricis* on *Carex divulsa,* and *P. conclusa* on *Cyperus difformis* (all three new to the country) and *P. conclusa* on *Cyperus difformis* were recently recorded during a survey of rust fungi on sedges in Pakistan. These rust species have the potential to serve as biological agents to control weeds and increase agricultural productivity. *Carex karoi* and *C. divulsa* are newly reported hosts for rust fungi in Pakistan.

Key words — Kaghan valley, Khyber-Pakhtoonkhwa, Punjab, *Uredinales*

Introduction

The *Cyperaceae* is a cosmopolitan family with 106 genera and ca. 5400 species (Govaerts et al. 2007) worldwide with 22 genera and 179 species known in Pakistan (Kukkonen 2001). Members of the *Cyperaceae* commonly called sedges are primarily grass-like herbs with linear leaves and parallel venation. The most important cyperaceous weeds in terms of their adverse effect on agriculture include *Cyperus difformis*, *C. esculentus*, *C. iria*, *C. rotundus*, and *Fimbristylis miliacea* (Bryson & Carter 2008). Among the important fungal pathogens of sedges are rust fungi (*Basidiomycota*: *Uredinales*). Previously, thirteen species of *Cyperaceae* have been reported as hosts for rust fungi from Pakistan (Ahmad et al. 1997; Afshan & Khalid 2008, 2009; Afshan et al. 2009). In the present study, four *Puccinia* taxa, three of them new records for Pakistan, are recorded on four cyperaceous hosts.

Materials & methods

During the survey of rust fungi from Pakistan, infected plants were collected from different areas of Pakistan. Healthy plants were collected along with inflorescences and fruits for accurate identification. Host plants were identified by comparing them with specimens in the herbarium of the Department of Botany, University of the Punjab, Lahore (LAH).

Free hand sections of infected portions of material and spores were mounted in lactophenol. Semi-permanent slides were prepared by cementing cover slips with nail lacquer (Dade & Gunnell 1969). Preparations were observed under a NIKON YS 100 microscope. Drawings of spores were made by using a Camera Lucida (Ernst Leitz, Wetzlar, Germany). Spores were measured using an ocular micrometer (Zeiss, St Albans, Hertfordshire, England). At least twenty-five spores were measured for each spore stage. Measurements include the usual range and the arithmetic means; extremes are given in parentheses.

Enumeration of Taxa

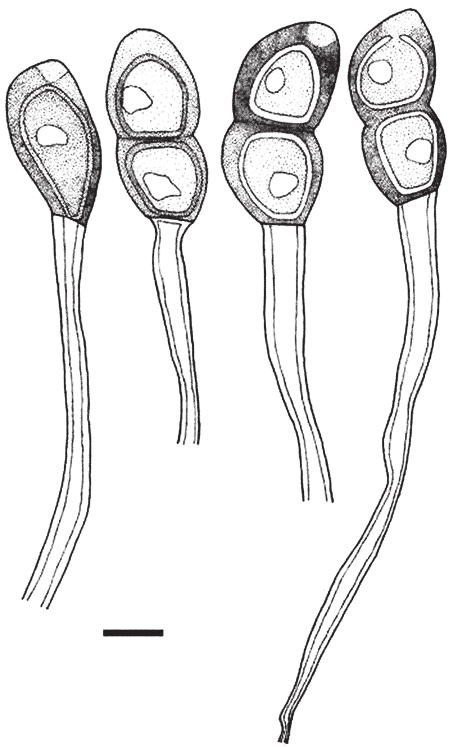

Fig. 1. Lucida drawings of 1–2 celled teliospores of *Puccinia caricis-kouriyamensis*. Scale bar = 15 µm.

Puccinia caricis-kouriyamensis Morim., J. Jap. Bot. 47(4): 117 (1972). Fig. 1

Spermogonia, aecia and uredinia not seen. Telia amphigenous, naked, black, scattered, compact, rounded, erumpent, pulverulent, 140–280 × 240–440 µm. Teliospores ellipsoid or oblong, pale brown to chestnut brown, constricted at septum, attenuate or rounded at base, 19–27 × 39–59(–63) µm (mean 22 × 50.8 µm); wall smooth, two-layered, pale brown to chestnut brown,

1.8–4.7 µm; germ pores two, one per cell, apical in upper cell, obscure in lower cell, most probably adjacent to septum; apex rounded or conical, dark brown with hyaline region, 4–9 µm thick; pedicel persistent, hyaline, 5–10 µm wide, 26–118 µm long. Mesospores intermixed, pale brown, sometimes chestnut brown, clavate to oblong, attenuated below, 14–24 × 31–53 µm (mean 18 × 40.8 µm); wall pale brown to dark brown, 1–2.4 µm, smooth; apex conical, pale brown to dark brown with hyaline region, 4–10 µm thick; pedicel hyaline, persistent, up to 73 µm long.

Material examined: **PAKISTAN**, **Gilgit Baltistan**, on *Carex karoi* Freyn, 26 July 2010, coll. & det. Malka Saba 01, with III stage (LAH 1140).

Rust fungi previously reported on *Carex* spp. from Pakistan include *Puccinia caricina* DC. and *P. caricis-filicinae* Barclay on *Carex filicina* Nees, *P. dioicae* Magnus and *P. pakistani* S. Ahmad on *Carex nubigena* D. Don, *P. bolleyana* Sacc. on *Carex flacca* Schreb., and *P. subepidermalis* Afshan et al. on *Carex curta* Gooden. (Ahmad et al. 1997, Afshan & Khalid 2009, Afshan et al. 2009).

Puccinia caricis-kouriyamensis, first reported on *Carex brunnea* Thunb. (kogome-suge) from Japan (Hiratsuka et al. 1992), is a new record for Pakistan. *Carex karoi* is a newly recorded host.

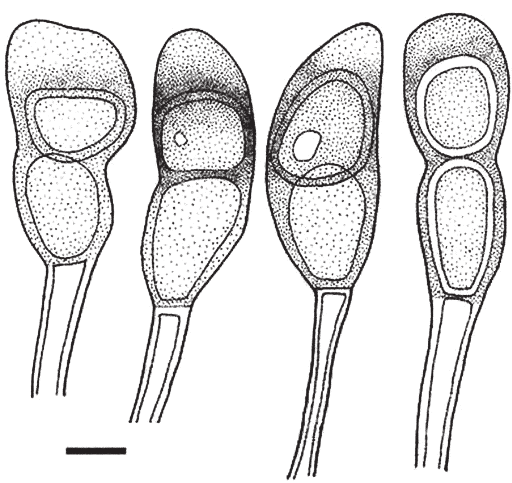

Fig. 2. Lucida drawings of teliospores of *Puccinia caricis-pocilliformis*. Scale bar = 10 µm.

Puccinia caricis-pocilliformis Morim., J. Jap. Bot. 49(8): 228 (1974). Fig. 2

Spermogonia, aecia and uredinia not seen. Telia on abaxial side of leaf, black, erumpent, scattered, first covered by epidermis, soon naked, compact, 80–200 × 100–600 µm. Teliospores clavate, obovate-clavate or oblong-clavate, yellowish brown to dark brown, constricted at septum, attenuated below,

(15–)18–24(–28) × (32–)37–60(–74) µm (mean 21.2 × 48.4 µm); wall smooth, yellowish brown or paler, two-layered, 1.5–2 µm; apex rounded, conical or obliquely conical, rarely truncate, dark brown, 6–17 µm thick; pedicel long, persistent, hyaline to pale yellow, 4–9.4 × (4–)7–71 µm. Mesospores present, clavate, pale brown, attenuated below, 13–15 × 36–47 µm (mean 13.6 × 39 µm); apex conical, 2–9 µm thick; pedicel short, up to 12 µm long.

Material examined: **PAKISTAN**, **Gilgit Baltistan**, on *Carex* L., 26 July 2010, coll. & det. Malka Saba 02, with III stage (LAH 1141).

Puccinia caricis-pocilliformis, first reported on *Carex tristachya* var. *pocilliformis* (Boott) Kük. (kotsubu-moegisuge) from Japan (Hiratsuka et al. 1992) , is a new record for Pakistan.

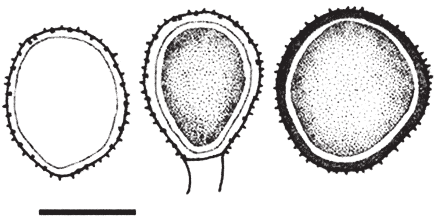

Fig. 3. Lucida drawings of urediniospores of *Puccinia conclusa*, showing echinulate ornamentation. Scale bar = 10 µm.

Puccinia conclusa Thüm., J. Sci. math. phys. nat. Lisboa, 1 Ser. 6(24): 237 (1878). Figs. 3–4

Spermogonia and aecia unknown. Uredinia amphigenous, mostly on abaxial side, brown, scattered, somewhat aggregated, erumpent, naked, 100–250 × 100–400 µm. Urediniospores subglobose, ellipsoid or obovoid, pale brown, 18–26 × 21–35 µm (mean 20.9 × 27 µm); wall pale brown, echinulate, 1–2(2.5–) µm; germ pores 2, equatorial; paraphyses absent. Telia amphigenous, black, loculate, covered with epidermis, aggregated, in groups, 90–110 × 90–170 µm. Teliospores cinnamon brown, clavate or fusiform, constricted at septum, attenuated below, 16–21 × 43–61 µm (mean 18.3 × 50 µm); wall cinnamon brown, smooth, 1–1.4 µm; apex rounded or conical, cinnamon brown to dark brown, 3–6 µm thick; pedicel persistent, pale brown, 6–9 × 8–41 µm.

Material examined: **PAKISTAN**, **Punjab**, Lahore, at 216 m a.s.l., *Cyperus difformis* L., 6 October 2010, coll. & det. Malka Saba 03, with II + III stages (LAH 1142).

Puccinia species previously reported on *Cyperus* in Pakistan include *P. cypericola* S. Ahmad and *P. philippinensis* Syd. & P. Syd. on *C. rotundus* L., *P. conclusa* [including misdeterminations as *P. romagnoliana* Maire & Sacc.] on *C. difformis* and *C. rotundus* from Chuharkana (Sheikhupura) and Karachi and on *C. iria* L.

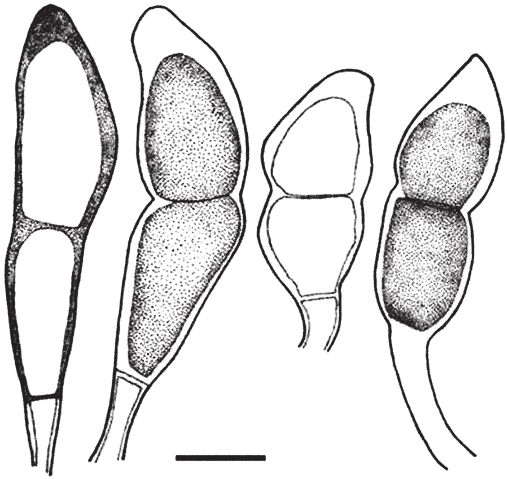

Fig. 4. Lucida drawings of teliospores of *Puccinia conclusa*. Scale bar = 10 µm.

from Lahore, and *P. cyperi-laevigati* Afshan & Khalid on *C. laevigatus* L. from Khanspur (NWFP) (Ahmad 1956a,b; Ghaffar & Kafi 1968, Hasnain et al. 1959, Afshan & Khalid 2008, Afshan et al. 2008).

Although *Puccinia conclusa* has been previously reported from other Pakistan localities, the Lahore collection is the first found on *Cyperus difformis,* a new host.

Puccinia extensicola* var. *linosyridis-caricis (E. Fisch.) Zwetko, Biblthca Mycol. 153: 109 (1993) . Fig. 5

Spermogonia and aecia not seen. Uredinia amphigenous, scattered in rows, golden brown, naked, covered with epidermis, 70–100 × 100–300 µm. Urediniospores sub-globose, ovoid or ellipsoid, pale brown, 16–24 × 20–27 µm (mean 20.5 × 23.4 µm); wall pale brown, echinulate, 1–2(–2.5) µm; germ pores 2, supraequatorial; pedicel hyaline, deciduous, 6–18 × 18–29 µm. Telia on abaxial side, dark brown to blackish brown, scattered in rows, naked, erumpent, 95–150 × 100–300 µm. Teliospores ellipsoid or oblong, cinnamon brown to dark brown, 16–26 × 39–64 µm (mean 21.5 × 51.4 µm), constricted at septum, attenuated at base; wall smooth, 1.5–3 µm; apex rounded, conical or sometimes truncated, dark brown, 8–15 µm; pedicel hyaline to pale brown, persistent, 5–13 × 15–41 µm.

Material examined: **PAKISTAN**, **Khyber-Pakhtoonkhwa**, Kaghan valley, Jalkhud, 3300 m a. s. l., *Carex divulsa* Stokes, 16 August 2009, coll. & det. Malka Saba 04, with II + III stages (LAH 1143).

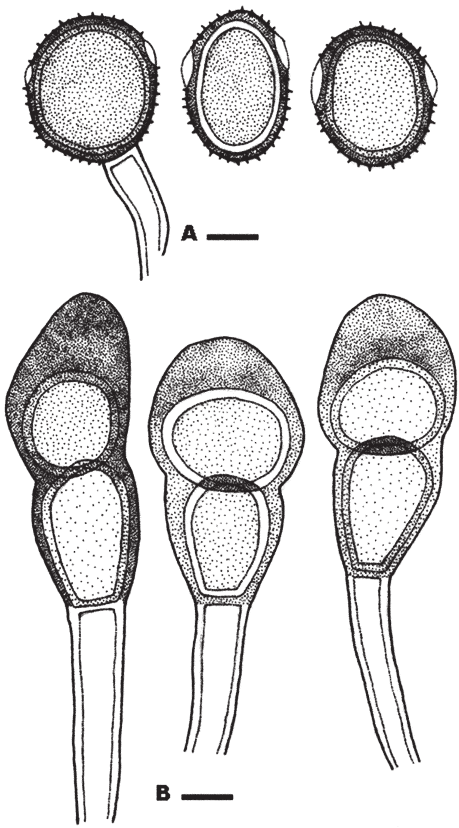

Fig. 5. Lucida drawings of *Puccinia extensicola* var. *linosyridis-caricis*.
(A) Urediniospores showing echinulate ornamentation and supraequatorial germ pores.
(B) Teliospores. Scale bar = 10 µm.

Puccinia extensicola var. *linosyridis-caricis,* first reported on *Carex humilis* Leyss. from Japan (Hiratsuka et al. 1992), is a new record for Pakistan, and *Carex divulsa* is a newly recorded host.

Key to the rust fungi on *Cyperaceae* in Pakistan

On *Carex*

1. Telia amphigenous 2
1. Telia hypophyllous, rarely amphigenous 4
2. Largest teliospore <50 µm long, oblong or oblong to clavate; teliospore apex 8–14 µm thick ..... *Puccinia caricis-filicinae*
2. Largest teliospore >50 µm long 3

3. Teliospore pedicel short, <10 µm; teliospore apex 4–6 µm thick; uredinial paraphyses clavate to capitate. . . . . *P. subepidermalis*
3. Teliospore pedicel long, >10 µm; teliospore apex 4–9 µm thick; uredinial paraphyses absent . . . . . *P. caricis-kouriyamensis*
4. Largest teliospore ≤60 µm long 5
4. Largest teliospore >60 µm long 7
5. Teliospore pedicel short, ≤10 µm . . . . . *P. pakistani*
5. Teliospore pedicel long, >10 µm 6
6. Teliospores clavate to oblong, 21–24 µm wide; urediniospore germ pores 2, equatorial . . . . . *P. bolleyana*
6. Teliospores clavate, 16–24 µm wide; urediniospore germ pores 2, supraequatorial . . . . . *P. dioicae*
7. Teliospore pedicel <50 µm long 8
7. Teliospore pedicel >50 µm long; teliospores obovate-clavate or oblong-clavate; apex ≤17 µm thick . . . . . *P. caricis-pocilliformis*
8. Urediniospore germ pores 3–4, equatorial . . . . . *P.caricina*
8. Urediniospore germ pores 2, supraequatorial. . . . *P. extensicola* var. *linosyridis-caricis*

On *Cyperus*

1. Urediniospore germ pores two, equatorial 2
1. Urediniospore germ pores >two, scattered; paraphyses clavate; teliospores 10–18 × (31–) 34–45 µm . . . . . *P. cyperi-laevigati*
2. Largest teliospore >50 µm long 3
2. Largest teliospore ≤50 µm long; teliospore apex ≤7 µm long; urediniospores 14–18 × 14–19 µm . . . . . *P. philippinensis*
3. Teliospore apex <10 µm thick; urediniospores 18–26 × 21–35 µm . . . . . *P. conclusa*
3. Teliospore apex >10 µm thick; urediniospores 15–20 × 20–25 µm . . . . . *P. cypericola*

On *Fimbristylis*

Urediniospores 11–18 × 18–23 µm, germ pores 3, supraequatorial; teliospores long ellipsoid or fusoid, 10–18 × 35–55 µm . . . . . *P. flavipes* Syd. & P. Syd.

On *Scirpus*

1. Teliospores two–celled; urediniospores 12–24 × 19–32 µm . . . . . *P. scirpi* DC.
1. Teliospores one-celled; urediniospores 18–24 × 24–34 µm . . . . . *Uromyces lineolatus* (Desm.) J. Schröt.

Acknowledgments

We sincerely thank Dr. Amy Rossman, Systematic Mycology and Microbiology Laboratory, USDA-ARS, Beltsville and Dr. Marcin Piatek, W. Szafer Institute of Botany, Polish Academy of Sciences, Poland for their valuable suggestions to improve the manuscript and acting as presubmission reviewers. We are cordially thankful to Dr. Shaun Pennycook, nomenclature editor, for reviewing the manuscript critically. We are

highly obliged to the Pakistan Science Foundation, Islamabad for funding this research work. We are also thankful to Dr. Najam-ul-Sehar Afshan and Dr. Abdul Rehman Khan Niazi for accompanying the first author on field trips and assistance in the field.

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